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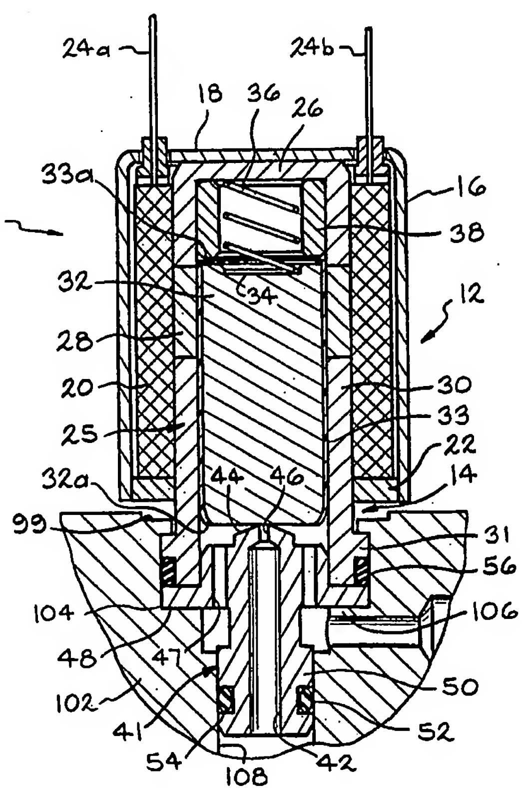
(54) Title: SLEEVE AND ARMATURE SUBASSEMBLY FOR CONTROL VALVES OF VEHICULAR BRAKING SYSTEMS AND METHOD OF FORMING

(57) Abstract

A control valve (10) for a vehicular braking system includes a valve subassembly (14) including an armature (32) slidably received in a flux tube (25). A solenoid subassembly (12) is mounted on the valve subassembly (14) for inducing a magnetic flux to slide the armature (32). A sleeve (33, 206, 465, 501) is fitted onto the armature (32) to reduce friction between the armature (32) and the flux tube (25). The sleeve (33, 206, 465, 501) is formed from a low-friction material. A method is disclosed for forming the armature (32) and the sleeve (33, 206, 465, 501) subassembly. The present control valve (10) has less hysteresis than previous control valves and can improve performance of a vehicular braking system.



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TITLE

SLEEVE AND ARMATURE SUBASSEMBLY FOR CONTROL VALVES OF VEHICULAR BRAKING SYSTEMS AND METHOD OF FORMING

CROSS-REFERENCE TO RELATED APPLICATIONS

This invention claims the benefit of United States provisional patent applications identified as Application No. 60/032,066, filed December 2, 1996 and Application No. 60/040,167, filed March 11, 1997.

BACKGROUND OF THE INVENTION

This invention relates in general to vehicular braking systems, and in particular is concerned with a low-friction sleeve and armature subassembly for a control valve in vehicular braking systems.

Hydraulic braking systems for vehicles are well known. A typical hydraulic braking system includes a master cylinder, fluid conduit arranged into a desired circuit, and wheel brake cylinders. The master cylinder generates hydraulic forces in the brake circuit by pressurizing brake fluid when the driver steps on the brake pedal. The pressurized fluid travels through the fluid conduit in the circuit to actuate brake cylinders at the wheels and slow the vehicle.

Anti-lock braking systems for vehicles are also well known hydraulic systems. A hydraulic control unit or housing, containing control valves and other components such as a pump, is located between the master cylinder and the wheel brake assemblies. Through an electronic controller, the control valves and other components selectively control pressure to the wheel brake assemblies to provide a desired braking response of the vehicle.

Many control valves are formed as electronically controlled solenoid valves. A typical solenoid valve includes an armature which reacts to magnetic

flux generated by a coil subassembly of the solenoid valve. An armature can be formed as a cylindrical element slidably mounted in a tube or sleeve. Many anti-lock braking systems include both normally open solenoid valves (isolation valves) and normally closed solenoid valves (dump/hold valves).

Solenoid control valves use lateral magnetic circuits and operate at high frequencies. While lateral magnetic circuits provide the axial output force versus displacement characteristics need for proportional hydraulic control, they usually suffer from significant detrimental lateral forces that can cause undesirable levels of hysteresis and slow performance. A reduction in such hysteresis can improve armature performance, and thus provide improved performance of a braking system. Various coatings of low friction materials have been applied to the outer surface of armatures to reduce hysteresis. However such coatings can be expensive and may be limited in thickness. Furthermore, it is desirable to improve the construction of control valves to reduce costs and the time required for assembly.

SUMMARY OF THE INVENTION

This invention relates to vehicular braking systems and solenoid control valves for such systems. The invention includes a sleeve and armature subassembly for control valves and a method for forming the subassembly. A sleeve is fitted on the armature to reduce hysteresis between the armature and a flux tube, also known as a sleeve, which slidably receives the armature. Furthermore, the sleeve can be formed from a relatively thick film (e.g., 0.20 mm) with eccentricity controlled (e.g., +/- 0.0025 on the armature and +/- 0.0050 mm on the flux tube) to provide a very desirable armature film thickness/eccentricity ratio.

In a preferred embodiment, a control valve for a vehicular braking system includes a valve subassembly including an armature slidably received in a flux

tube. A solenoid subassembly is mounted on the valve subassembly for inducing a magnetic flux to slide the armature. A sleeve is fitted onto the armature to reduce friction between the armature and the flux tube. The sleeve is formed from a low-friction material. A method is disclosed for forming the armature and sleeve subassembly. The present control valve has less hysteresis than previous control valves and can improve performance of a vehicular braking system.

The flux tube according to this invention can be formed as a three piece subassembly including a non-ferromagnetic section disposed between two ferromagnetic sections. Furthermore, the present valve subassembly includes a valve body having a cap. A fluid passageway is provided in the valve body and the cap. The cap acts as a valve seat for the armature and/or a valve element to control fluid flow through the control valve.

Various objects and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiment, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a control valve according to the present invention mounted on a hydraulic control unit of a vehicular anti-lock braking system.

FIG. 2 is a partly sectional view illustrating an expanded tubing being slid onto an armature for forming a low-friction sleeve and armature subassembly for use in the control valve of FIG. 1.

FIG. 3 is a partly sectional view illustrating chamfered ends of the tubing after it has been slid onto the armature and heated as desired.

FIG. 4 is an enlarged, partial view of a sleeve and armature subassembly according to the present invention after grinding has reduced the thickness of a cylindrical portion of the sleeve as desired.

FIG. 5 is a schematic view of one embodiment of a vehicular braking system in which the control valve of FIG. 1 can be incorporated.

FIG. 6 is a sectional view of a second embodiment of the present control valve illustrated as both a normally open isolation valve and a normally closed hold/dump valve in a schematically illustrated vehicular braking system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A fluid control valve according to the present invention is indicated generally at 10 in FIG. 1. The valve 10, which can be a proportional valve, is particularly suited to regulate brake fluid pressure in vehicular braking systems such as an anti-lock braking system (ABS), a traction control braking system (TCS), or an electronic brake management system (EBM). The valve 10 includes a solenoid subassembly 12 connected or secured to a valve subassembly 14.

The solenoid subassembly 12 includes a cup-shaped housing or casing 16. Preferably, the casing 16 is a drawn member having a generally large area and a planar end surface 18. A coil 20, preferably a bobbin-less coil, is placed inside the casing 16. At its outer diameter, the coil 20 can be wrapped with a suitable tape (not illustrated) for protection and retention of a coil lead tower washer (not illustrated). A flux ring 22 is pressed into the casing 16 to secure the coil 20. A pair of winding terminals 24a and 24b extend outwardly through respective openings in the end surface 18 of the casing 16 and are adapted to be connected

to an electronic control module (not illustrated) for inducing a magnetic field in a well known manner.

The solenoid subassembly 12 is pressed onto a flux tube or sleeve 25 of the valve subassembly 14. The flux tube 25 can be formed as a three-piece subassembly having a first, cup-shaped ferromagnetic section 26, a second, cylindrical non-ferromagnetic section 28, and a third, cylindrical ferromagnetic section 30. The sections 26, 28, and 30 can be friction welded together and then machined to a desired finish. Alternatively, the sections 26, 28, and 30 can be oven brazed or laser welded together. Also, the sections 26, 28, and 30 may be made as a metal injection molding. A radial flange 31 is formed about a lower portion of the third section 30 which extends downwardly beyond the flux ring 22 when the solenoid subassembly 12 is pressed onto the flux tube 25.

A cylindrical armature 32 is slidably received within the flux tube 25. The armature 32 can be formed as an iron cylinder. Preferably, the armature 32 is formed with at least one chamfered end 32a. Preferably, a non-magnetic sleeve 33 is snugly fitted about at least the axial length of the armature 32. The sleeve 33 is formed from a low-friction material and preferably has a substantially uniform wall thickness. A preferred material for the sleeve 33 is polytetrafluoroethylene, commonly known by the trademark Teflon. Other preferred materials for the sleeve 33 include fluorocarbons. A chamfered ends 33a of the sleeve 33 may be rounded over an upper end of the armature 32. In other embodiments, the sleeve 33 can be cut even with the ends of the armature 32. Preferably, the armature 32 and sleeve 33 are formed as a subassembly prior to positioning within the flux tube 25. The sleeve 33 reduces friction between the armature 32 and flux tube 25 and reduces hysteresis of the armature 32. Furthermore, the sleeve 33 established the magnetic gap between the armature 32 and the flux tube 25. This magnetic gap is substantially uniform due to the substantially uniform thickness of the sleeve 33. Also, the sleeve 33 is relatively

thick when compared to coatings and a desired sleeve thickness/eccentricity ratio.

When the coil 20 is energized, a magnetic field is generated causing magnetic flux to pass from the third section 30 through the sleeve 33 to the armature 32, and then through the sleeve 33 to the first section 26. The magnetic flux does not travel through the second section 28. The flux tube 25, flux ring 22 and casing 16 cooperate together to provide a complete path for the magnetic flux.

A recess 34 formed in an outer end of the armature 32 receives a spring 36, illustrated as a coil spring. An opposite end of the spring 36 is received by the cup-shaped first section 26 of the flux tube 25. A hollow cylindrical spacer 38 is used to center the spring 36 within the first section 26. In this construction, spring 36 provides a force to bias the armature 32 away form the outer end 18 of the casing 16. When the magnetic field is induced, the armature 32 is urged toward the outer end 18 of the casing 16 and compresses spring 36. Preferably the inner surfaces of the sections 26, 28, and 30 of the flux tube 25 are burnished and the outer surface of the armature 32 is ground so that these surfaces are highly concentric to minimize lateral (radial) forces, coulomb friction and hysteresis. The sleeve 33 provides concentricity and resists friction to reduce hysteresis.

A drop-in assembly is desired for the spacer 38, spring 36, and armature 32. These elements can be easily slid into the interior volume of the flux tube 25 without any special assembly techniques.

The inner end of the third section 30 of the flux tube 25 is placed against a valve body 41. Preferably, the valve body 41 is formed from a non-magnetic material so that the valve body 41 is not part of the magnetic circuit formed when the coil 20 is energized. The valve body 41 may be formed from plastic, aluminum, or steel, as well as other desired materials.

In the embodiment illustrated, the valve body 41 is a generally cylindrical member having an axial passageway 42. An upper end of the valve body 41 is formed as an outwardly projecting cap 44. Preferably, an outer surface of the cap 44 terminates in an apex, illustrated in this embodiment as a conical portion. A passageway 46 is formed in the cap 44 concentric with passageway 42. An outer surface of the cap 44 acts as a valve seat for a lower end surface of the armature 32. If desired, a valve element such as a disc or a ball (neither of which is illustrated) can be disposed between the end surface of the armature 32 and the cap 44 to assist in blocking fluid flow. At least one fluid passageway 47 is formed in the valve body 41 radially outwardly from passageway 42. A radial flange 48 is formed about an outer surface of the valve body 41. A reduced diameter portion 50 is formed in a lower portion of the valve body 41.

The valve body 41 is received in a stepped opening or bore 104 formed in a hydraulic control unit (HCU) 102 of a vehicular braking system. The bore 104 includes a first step or shoulder 106 which receives a lower surface of the flange 48. An inner reduced diameter portion 108 of the bore 104 receives the reduced diameter portion 50 of the valve body 41. A seal 52 received in an annular groove 54 formed in an outer surface of the lower portion 50 of the valve body 41 provides a fluid seal between the valve body 41 and the HCU 102. A seal 56 is trapped between the flange 31 of the flux tube 25 and the radial flange 48 of the valve body 41 to provide a fluid seal.

The control valve 10 is significantly smaller than other known proportional solenoid valves. For example, valve 10 can be constructed with a 24 mm diameter and a length of 52 mm. Valve 10 is easier to assembly, more resistant to contamination, and uses less current than other known proportional control valves. For example, in one embodiment, valve 10 uses only 0.35 amp during periods of pressure change.

In a preferred method of assembly, various components are stacked together and then retained on the HCU 102 by a single orbital swaging operation. The spring 36, spacer 38, and armature 32 are inserted into the flux tube 25. The valve body 41 with seal 52 is pressed into place (preferably with a low force) into the bore 104. Seal 56 is trapped between the flux tube 25 and the valve body 41. An annular lip 99 is formed from material surrounding the bore 104. The lip 99 can be formed by any desired metal-forming technique, including orbital swaging. The lip 99 formed by a single process retains the valve 10 on the HCU 102 and holds the components of the valve 10 together, all in one operation.

The present valve 10 controls fluid flow with a poppet seat provided by cap 44 and disc 40. Such a poppet seat is highly resistant to contamination and is highly resistant to leakage. The solenoid valve sensitivity (i.e., valve flow opening/[pressure demand - pressure output]) of valve 10 is controlled by the spring rate of spring 36 and not by the magnetic circuit spring rate since the preferred magnetic spring rate is zero (flat). If valve sensitivity needs to be changed for larger brake systems, then merely a spring 36 with a different spring rate need be changed.

In a vehicular braking system, a pair of valves 10 can be used to control braking at a wheel. One valve 10 can be configured as a normally closed valve as illustrated in FIG. 1, and one valve can be configured as a normally open valve as discussed below. For example, in an electronically controlled hydraulic brake system, one valve 10 can be used to control pressure apply while a second valve 10 can be used to control pressure release. Only one valve 10 is energized at a time and only during peak periods of pressure change. On long downhill grades with long periods of unchanged brake pressure holding, the valve 10 will draw no current, thereby greatly reducing solenoid valve heat dissipation.

During energization, the magnetic forces of valve 10 tend to be close to a linear function of current, rather than a function of current squared, as is the case with many magnetic circuits. This aspect of valve 10, which results from the configuration and sizing of the armature 32 and flux tube 25 and associated primary air gap, produces a valve whose output sensitivity to input control currents is substantially uniform (at both high and low brake fluid pressures), thus making pressure control proportional to current.

A preferred method for forming the subassembly comprising the sleeve 33 and the armature 32 is illustrated in FIGS. 2-4 as successive steps. The method involves the use of a tool 200 having a downwardly projecting annular step 202 and a passageway 204 preferably aligned with an axis of the step 202. The tool 200 can be positioned as desired with respect to an armature 32. Shrink tubing 206 formed from a flexible, low-friction material is used with the tool 200.

The armature 32 is provided. A predetermined length of tubing 206 is provided and mounted about the step 202. Pressurized air travels through the passageway 204 to expand the predetermined length of tubing 206. When unexpanded, the inner diameter of the tubing 206 is preferably less than the outer diameter of the armature 32. Also, pressurized air increases column strength of the tubing 206 to prevent buckling or collapsing as the armature 32 is slid into the tubing 206.

The tool 200 with the tubing 206 is moved downwardly toward the armature 32 so that the tubing 206 slides over the chamfered end 32a of the armature 32 as illustrated in FIG. 2. The chamfered end 32a leads the tubing 206 onto the armature 32 and provides an initial pressure seal with the tubing 206. The pressurized air expands the length and diameter of the tubing 206 for easier installation onto the armature 32 and results in residual hoop stress to retain the sleeve 33 on the armature 32. This procedure avoids unsymmetrical

circumferential shrinkage. The pressurized air also acts as an air bearing between the armature 32 and the tubing 206 to reduce installation friction.

The tubing 206 is heated to form the subassembly of the armature 32 and sleeve 33. As illustrated in FIG. 3., heat allows additional conforming of the tubing 206 to the armature 32 and causes the ends 206a to round over around the ends of the armature, resulting in the chamfered ends 33a of the sleeve 33. Ends 206a relieves and bending stress at the end corners which could otherwise cause the cylindrical portion of the sleeve 33 to separate from the armature 32.

The armature 32 and tubing 206 can undergo a grinding process to accurately set the subassembly diameter. For example, the grinding step can be accomplished by a centerless grinding operation using a grinding wheel and a follow wheel. The centerless grinding operation accurately reduces the thickness of the cylindrical portion of the tubing 206as compared to the thickness of the ends 206a. A cutting process removes portion of the tubing 206 from an end of the armature 32 which engages the valve body 41, as illustrated in FIG. 4. Once the proper diameter has been set and the end portion removed, the armature 32 and sleeve 33 subassembly can be used with control valve 10 as illustrated in FIG. 1.

Tubing 206 formed from polytetrafluoroethylene has been successfully used. Centerless grinding has resulted in accurate armature core diameter (+/- 0.0025 mm), accurate armature-sleeve subassembly diameter (+/- 0.0025 mm), and an accurate thickness, low-friction sleeve 33 that is well attached to the armature 32. By using 0.20 mm low-friction tubing 206 in this method, and +/- 0.0025 mm eccentricity on the armature 32 and +/- 0.0050 eccentricity on the flux tube 25, desirable results have been obtained. A control valve 10 with the present armature 32 and sleeve 33 produces a low hysteresis versus proportional output by having a high ratio of armature non-magnetic gap thickness versus armature positional eccentricity.

A vehicular braking system indicated generally at 300 in FIG. 5 represents one example of a braking system which can incorporate the control valve 10 with its armature 32 and sleeve 33 presented above. In system 300, a brake pedal 310 is connected to a master cylinder 312 to provide pressurized brake fluid to a wheel brake 314. In the embodiment illustrated in FIG. 5, the wheel brake 314 is illustrated as a disc assembly; however, the wheel brake 314 may be any type found on vehicles.

A hydraulic control unit (HCU) 302 is a housing for valves and other components as described below. For purposes of clarity of illustration, only one set of components are illustrated in FIG. 5. Typically, however, the HCU 302 also houses corresponding components for other wheels of the vehicle.

The HCU 302 includes a normally open isolation valve 316 disposed between the master cylinder 312 and the wheel brake 314, at least one low pressure accumulator 318, a normally closed hold/dump valve 320 disposed between the wheel brake 314 and the low pressure accumulator 318, and a hydraulic pump 322 connected between the low pressure accumulator 318 and an inlet to the isolation valve 316. The HCU 302 may also include an attenuator 324 between an output of the pump 322 and the inlet to the isolation valve 316 to limit and smooth fluid flow from the pump 322 back to the master cylinder 312. Various fluid passageways are provided in the HCU 302 to connect the various components.

The isolation valve 316 and the hold/dump valve 320 are control valves preferably formed as electrically actuated solenoid valves. The isolation valve 316 is preferably formed as a two position, solenoid valve having a normally open configuration. The hold/dump valve 320 is preferably formed as a two position, solenoid valve having a normally closed configuration. The valves 316 and 320 are switched by an electronic control module (not illustrated) to provide anti-lock braking in a well known manner.

As described above, control valve 10 is a solenoid valve having a normally closed configuration. Control valve 10 can be substituted for hold/dump valve 320 to perform in system 300. The low hysteresis provided by control valve 10 results in better performance of system 300. The pressure output of control valve 10 is a function of current to the valve 10 times the input pressure to the valve 10. By varying the current and knowing the input pressure, the output pressure can be controlled.

In other embodiments, a control valve 10 according to this invention incorporating the above-described armature 32 and sleeve 33 can be configured as a normally open solenoid valve. For example, a second vehicular braking system is indicated generally at 400 and illustrated in FIG. 6. As described below, system 400 includes a normally open isolation valve 422 incorporating an armature and sleeve as described above.

In system 400, a brake pedal 412 is connected to a master cylinder 414. A fluid conduit 416 is connected between the master cylinder 414 and an inlet port 418 formed in a hydraulic control unit (HCU) 420. Preferably, the HCU 420 is a housing formed from a suitable lightweight material which includes bores for receiving various components and internal conduits connecting such components.

A first solenoid valve 422 functions as an isolation and proportional reapply valve as described below. Isolation valve 422 includes a valve body 424 received in a first bore 426 of the HCU 420. The valve body 424 has a radial flange 428, a first internal channel 430 and a second internal channel 432. After the valve body 424 has been inserted into the bore 426, an annual lip 434 is formed by swaging material of the HCU 420 adjacent the bore 426 to retain the valve body 424 on the HCU 420. The second channel 432 is aligned with an outlet port 436 formed in the HCU 420. The outlet port 436 is in fluid communication with a fluid conduit 437. A seal 438 is received in a groove

formed in an outer surface of the valve body 424 to provide a seal between the inlet port 418 and the outlet port 436.

The isolation valve 422 also includes a coil assembly 440. The coil assembly 440 is inserted onto the valve body 424 and can be retained by a cover assembly or an electronic control module assembly (neither of which is illustrated) or the like, which is pushed downwardly onto the coil assembly 440. A cup-shaped housing or casing 442 provides a flux return path. A coil 444, preferably an epoxy bound bobbin-less coil, is placed around a flux tube 446. A flux ring 448 is pressed into the casing 442 to secure the coil 418 and complete the flux return path. Preferably, the flux ring 422 is machined to minimize air gaps between the casing 442 and the flux tube 446. A pair of winding terminals 450A and 450B extend outwardly through respective openings in the casing 442 and are adapted to be connected to an electronic control module (not illustrated) for inducing a magnetic field through the flux tube 446 in a well known manner.

Preferably, the flux tube 446 is formed as a three-piece cylindrical member having a first, cup-shaped ferromagnetic section 452, a second, cylindrical non-ferromagnetic section 454, and a third, cylindrical ferromagnetic section 456. When induced by the coil 444, the magnetic field passes through the first and third sections 452 and 456, and not the second section 454.

A cylindrical armature 458 is slidably received within the flux tube 446. A spring 460 is seated at one end on a spring seat 462 formed on the lower end of the armature 458. The spring 460 is seated at its opposite end on a spring seat 464 formed on an upper end of the valve body 424. The solenoid valve 422 is normally open as the spring 460 urges the armature 458 away from the valve body 424 with a low spring force. When the coil 444 is energized, the armature 458 is urged downwardly against the spring 460 by magnetic forces until spring seat 462 contacts spring seat 464 to close the isolation valve 422. The magnetic

force works against the pressure differential across a valve seat formed by the spring seats 462 and 464.

Preferably, the flux tube 446 is roll burnished and the outer diameter of the armature 458 is ground to provide very precise positional concentricity of the armature 458, thereby minimizing lateral forces. Furthermore, a low-friction sleeve 465 fitted on the armature 458 (like sleeve 33 on armature 32) will provide low friction between the armature 458 and the flux tube 446 and minimize hysteresis. The magnetic configuration of the isolation valve 422 provides a lateral working air gap in which the magnetic permeance is a linear function of axial travel. Thus, the axial magnetic force is proportional to current and independent of the travel of the armature 458 in its operating range. In this manner, proportional control of the isolation valve 422 is stable and controlled.

A second solenoid valve 466 functions as a proportional dump valve as described below. Dump valve 466 is a normally closed valve having a valve body 468 and a coil assembly 470. The valve body 468 is preferably retained in a bore 472 in the HCU 420 by an annular swaged lip 474. A first channel 476 is in fluid communication with an inlet port 478 formed in the HCU 420. A second channel 480 is in fluid communication with an outlet port 482 formed in the HCU 420. Outlet port 482 is in fluid communication with an inlet line 484 of a hydraulic pump 486.

The coil assembly 470 includes a casing 488, a coil 490, a flux tube 492, and an armature 494 slidably received inside the flux tube 492. Preferably, the flux tube 492 is formed as a three-piece cylindrical member having a first, cup-shaped ferromagnetic section 496, a second, cylindrical non-ferromagnetic section 498, and a third, cylindrical ferromagnetic section 500. When induced by the coil 490, the magnetic field passes through the first and third sections 496 and 500, and not the second section 498. A low-friction sleeve 501 is fitted on the armature 494 (like sleeve 33 on armature 32) to provide low friction between

the armature 494 and the flux tube 492 and minimize hysteresis. A spring 502 is received in a cavity 504 formed in an upper portion of the armature 494 and urges the armature downwardly so that a lower surface 506 of the armature 494 contacts a valve seat 508 formed on an upper surface of the valve body 468.

The pump 486 outlet is connected to conduit 416 and delivers fluid to inlet port 418. A check valve 510 permits only one-way fluid flow from conduit 437 to conduit 416. A pressure transducer 512 reduces the effects of varied pressure from the master cylinder 414 during certain modes of the system 400 as described below.

During normal braking of the system 400, i.e., not anti-lock braking, both solenoid valves 422 and 466 are not energized and the pump 486 is not operated. An operator presses the brake pedal 412 to release fluid pressure from the master cylinder 414 to conduit 416. Increased fluid pressure travels through inlet port 418 and channel 430, past spaced-apart spring seats 464 and 462 to channel 432 and outlet port 436 to conduit 437. Pressurized fluid reaches a wheel brake 514, illustrated as a caliper, to cause braking of a wheel rotor 516.

During anti-lock braking, i.e., when wheel lockup is imminent, the pump 486 is operated and the solenoid valves 422 and 466 are energized. By energizing the isolation solenoid valve 422, the armature 458 slides downwardly to engage the valve body 424 and block fluid flow from the master cylinder 414 to the wheel brake 514. The dump solenoid valve 466 is opened as the armature 494 is pulled upwardly away from the valve body 468 so that fluid pressure is relieved from the wheel brake 514 through inlet port 478, outlet port 482 and conduit 484.

As the vehicle wheels start spinning up and pass a target slip level, the dump valve 466 is de-energized and the voltage to the isolation valve 422 is reduced to a predetermined stored value plus a second value which is a function of the master cylinder 414 pressure. This causes the isolation valve 422 to

quickly reapply a pressure to the brakes that is a function of the stored voltage. The stored voltages are retained in the electronic control module (not illustrated). Afterwards, current to the isolation valve 422 is decreased at a controlled rate which is also a function of master cylinder 414 pressure, thereby causing brake pressure to increase at a relatively slow rate after a proportional quick reapply of the isolation valve 422.

If lockup is not again imminent after a predetermined interval (e.g., approximately 0.75 seconds), the isolation valve 422 current is decreased at a faster rate, thereby providing a faster brake pressure reapply for this portion of the anti-lock braking cycle.

When lockup is again imminent, the voltage of the isolation valve 422 is first stored. Next, the isolation valve 422 is fully energized and the dump valve 466 is energized. The stored voltage indicates the pressure needed to lockup a when under the conditions of the previous cycle and is used to control the next reapply cycle.

For the next reapply cycle, a proportion of the stored voltage is quickly applied to the isolation valve 422, followed by a slowly decreasing voltage. Thus, a fast proportional reapply is followed by a slow reapply as described above.

Similar logic can be used for proportional dump control. A quick increase in dump valve 466 current can be followed by a slower increase until the vehicle wheels start spinning up again. If the wheels do not start spinning up after a desired interval (e.g., approximately 0.20 seconds), the dump current rate can be increased. The value of the current at which the wheels start to spin up is stored and used on the next dump cycle, thus providing proportional pressure dump.

The isolation valve 422 provides a reapply pressure that is an inverted function of current and is based on master cylinder pressure. Thus the pressure transducer 512 is beneficial in providing input to adjust control current to

diminish effects of varied master cylinder pressure on reapply pressures to the wheel brake 514.

In the system 400, proportional reapply is always provided using decreasing isolation valve 422 voltage and the proportional release option is always provided using increasing dump valve 466 voltage. Both magnetic and coulomb hysteresis are diminished since each valve 422 and 466 is controlled from one direction. Additionally, since the inputs are valve voltages and essential feedback is wheel behavior, variations from valve to valve and variations due to temperature can be substantially diminished.

In accordance with the provisions of the patent statutes, the principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

CLAIMS

What is claimed is:

1. A control valve for a vehicular braking system comprising:

a valve subassembly including an armature slidably received in a flux tube;

a solenoid subassembly mounted on the valve subassembly for inducing a magnetic flux to slide the armature; and

a sleeve fitted onto the armature to reduce friction between the armature and the flux tube.

2. The control valve defined in Claim 1 wherein the sleeve is formed from a low-friction material.

3. The control valve defined in Claim 2 wherein the sleeve is formed from polytetrafluoroethylene.

4. The control valve defined in Claim 1 wherein the armature is a cylindrical member and the sleeve covers at least a substantial portion of an axial length of the armature.

5. The control valve defined in Claim 1 wherein the flux tube is a three piece construction having a non-ferromagnetic section disposed between two ferromagnetic sections.

6. The control valve defined in Claim 1 wherein the valve subassembly includes a valve body having a fluid passageway terminating in a cap facing the armature, wherein the flux tube is pressed onto the valve body so

that movement of the armature will selectively open or close the fluid passageway of the valve body.

7. The control valve defined in Claim 6 wherein the valve body is formed from plastic.

8. The control valve defined in Claim 6 wherein the armature is biased onto the cap of the valve body when the solenoid subassembly is not energized.

9. The control valve defined in Claim 6 wherein the armature is biased away from the cap of the valve body when the solenoid subassembly is not energized.

10. The control valve defined in Claim 1 wherein the sleeve provides a thick magnetic gap between the armature and the flux tube.

11. In combination, a control valve for a vehicular braking system and a hydraulic control unit having a bore therein comprising:

a valve subassembly including a valve body formed as a generally cylindrical member having a radial flange, wherein the valve body is received in the bore of the hydraulic control unit,

a flux tube containing a slidable armature secured to the valve body, wherein the flux tube is formed from a non-ferromagnetic section disposed between two ferromagnetic sections; and

a solenoid subassembly including a casing, a coil, and a flux ring secured to the valve body.

12. The combination defined in claim 11 including a sleeve fitted on the armature to reduce friction between the armature and the flux tube.

13. The combination defined in Claim 12 wherein the sleeve is formed from a low friction material.

14. The combination defined in Claim 13 wherein the sleeve is formed from polytetrafluoroethylene.

15. The combination defined in Claim 14 wherein the armature is a cylindrical member and the sleeve covers at least a substantial portion of an axial length of the armature.

16. The combination defined in Claim 11 including a disc disposed between the armature and the valve body.

17. A method for forming a sleeve and armature subassembly for a control valve of a vehicular braking system, the method comprising the steps of:

providing an armature;

providing a predetermined length of tubing formed from a low-friction material;

expanding the predetermined length of tubing;

sliding the expanded tubing onto the armature; and

heating the tubing so that the tubing conforms to the armature.

18. The method defined in Claim 17 including the step of grinding the tubing to a desired outer diameter after the step of heating.

19. The method defined in Claim 17 wherein the tubing has an unexpanded inner diameter less than an outer diameter of the armature.

20. The method defined in Claim 17 wherein the tubing is formed from polytetrafluoroethylene.

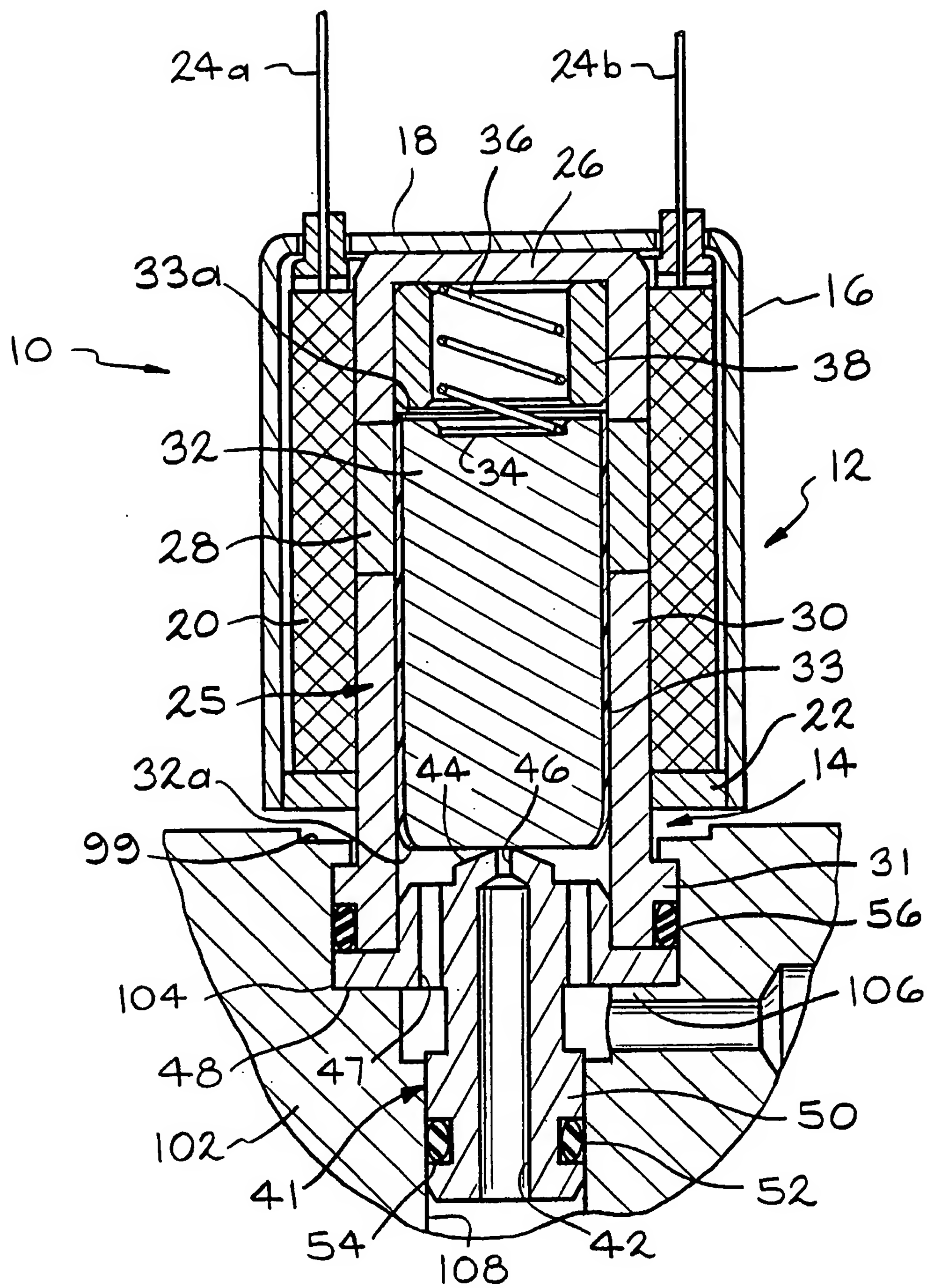
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FIG. 1

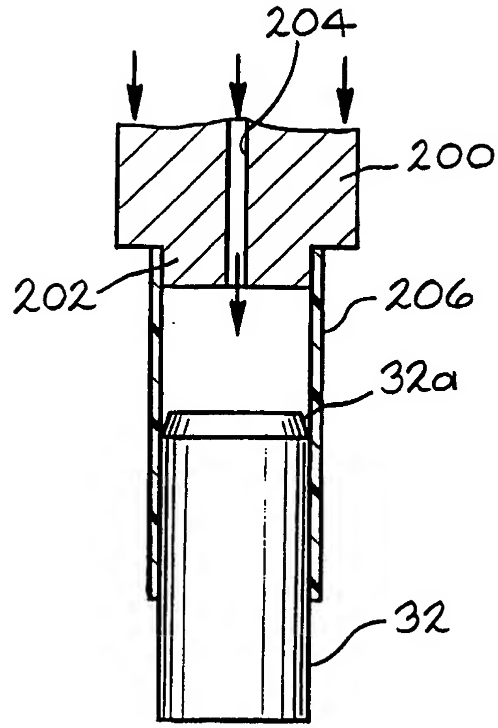

FIG. 2

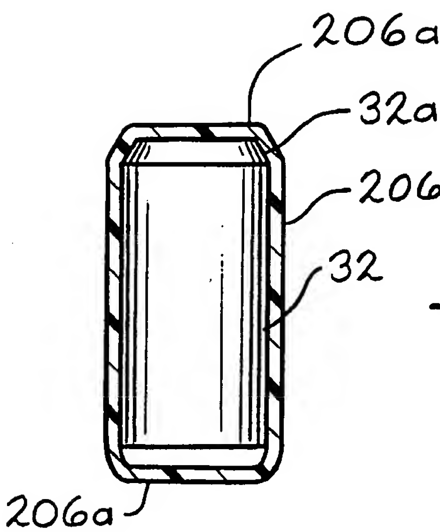

FIG. 3

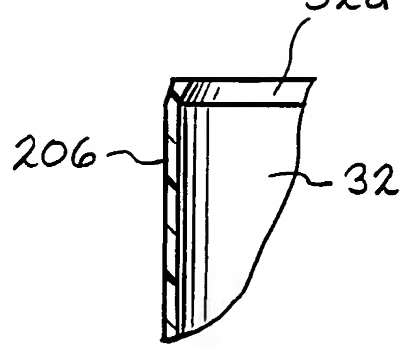

FIG. 4

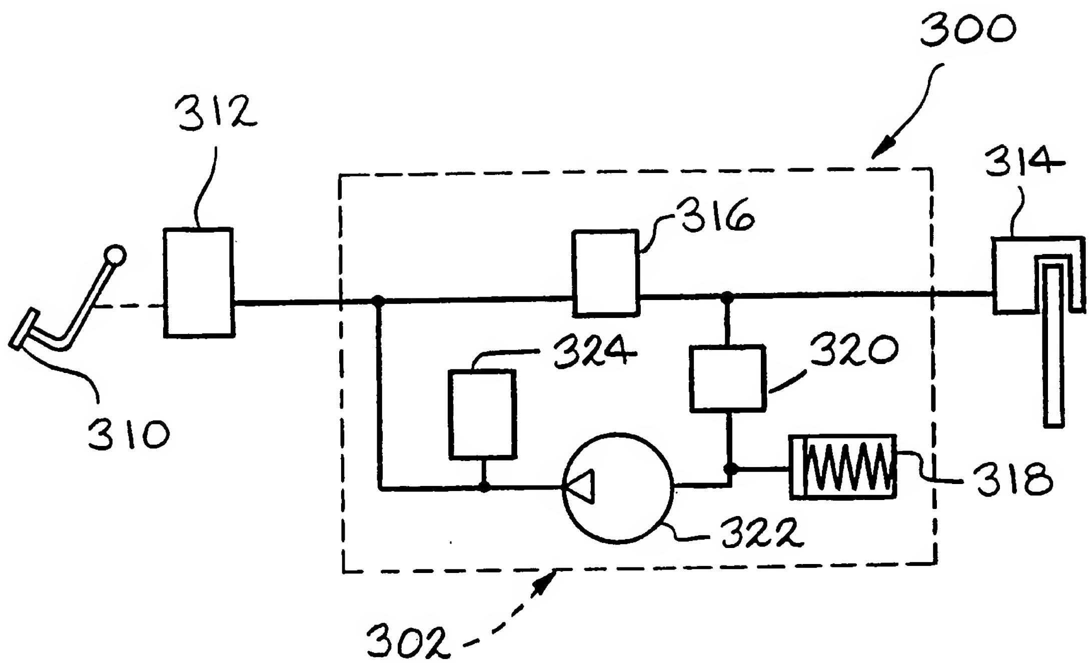

FIG. 5

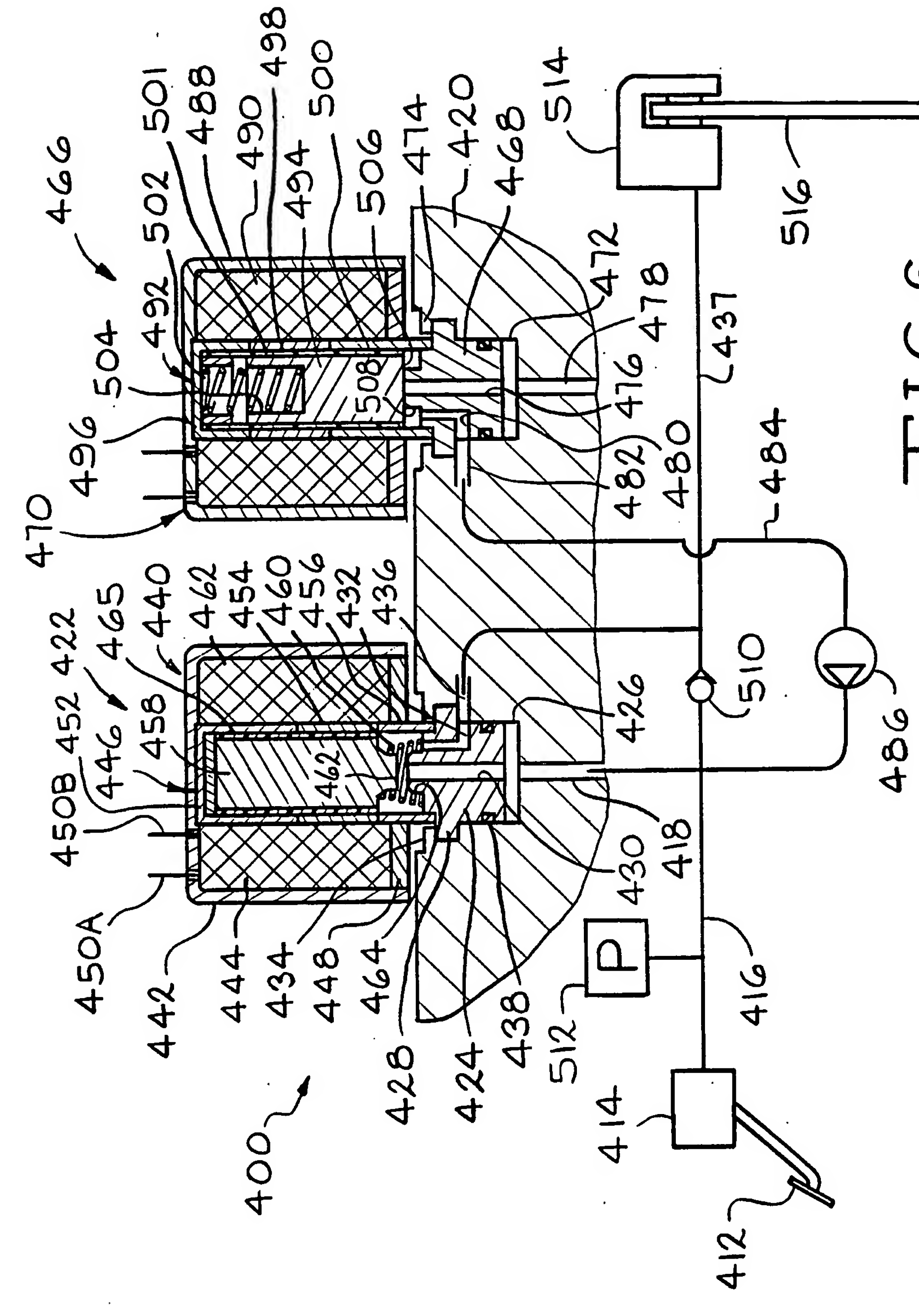
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FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/04824

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60T8/36 F16K31/06 H01F7/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60T F16K H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 004 343 A (MARSDEN JOHN THOMAS) 25 January 1977 see column 2, line 30 - line 37; figure 1	1,2,5,10
Y		3
A		12,13,17

Y	US 4 896 860 A (TORRENCE ROBERT J ET AL) 30 January 1990 see column 3, line 18 - line 40; figures	3
A		1,2,10, 12-14,20

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 July 1998	28. 07. 1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Meijs, P

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 785 848 A (LEIBER HEINZ) 22 November 1988 see column 3, line 25 - line 34 see column 4, line 32 - line 34 see column 4, line 42 - line 52 see column 7, line 38 - line 41 see figures 1,2,4 ---	11-13,15
Y	DE 22 36 586 A (DUNGS KARL FA) 7 February 1974 see page 1, paragraph 1 - page 5, paragraph 1; figures ---	11-13,15
A	CH 309 663 A (HERION ERICH) 16 November 1955 see the whole document ---	
Y	US 3 829 060 A (VON LEWIS A) 13 August 1974 see figures 1,2 ---	11
Y	EP 0 559 067 A (SUMITOMO ELECTRIC INDUSTRIES) 8 September 1993 see column 1, line 7 - column 2, line 15; figure 2 see column 3, line 10 - line 14; figure 1 ---	11
A	DE 35 02 730 A (RAUSCH & PAUSCH) 31 July 1986 see page 3, last paragraph - page 4, paragraph 2; claims 1-6; figure 1 ---	1-4,6,8, 10, 12-17,20
A	US 4 553 735 A (BRUNDAGE ROBERT W) 19 November 1985 see column 8, line 67 - column 9, line 17; figures ---	1-6,8, 10-15, 17,20
A	US 3 817 491 A (BURCKHARDT M ET AL) 18 June 1974 see column 1, line 5 - line 8 see column 2, line 22 - line 24; figure ---	1-4,6,8, 10, 12-15, 17,20
A	US 4 714 234 A (FALK THEODORE J ET AL) 22 December 1987 see column 6, line 58 - line 65; figure 3 ---	1-4, 12-15, 17,20

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 20 52 307 A (TEVES GMBH ALFRED) 25 May 1972 see page 1, paragraph 1 see page 4, paragraph 1 - paragraph 2 see page 7, last paragraph - page 8, paragraph 1; figures 1,2 ---	1,5,6, 8-10
A	DE 44 31 457 A (BOSCH GMBH ROBERT) 7 March 1996 see claim 3; figures ---	7
A	US 3 989 063 A (BROUWERS SYTZE ET AL) 2 November 1976 see column 2, line 20 - line 25 see column 3, line 24 - line 30; figure 1 ---	11,16
A	US 4 828 335 A (FULLER EDWARD N ET AL) 9 May 1989 see the whole document -----	11

3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 98/04824

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

CLAIMS 1-10, 17-20
CLAIMS 11-16

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/[illegible] 98/04824

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/04824

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